Role of the Infralimbic Cortex in Pavlovian Conditioning of Rhesus Monkeys: Development of an Electrocardiograph Quality Indicator

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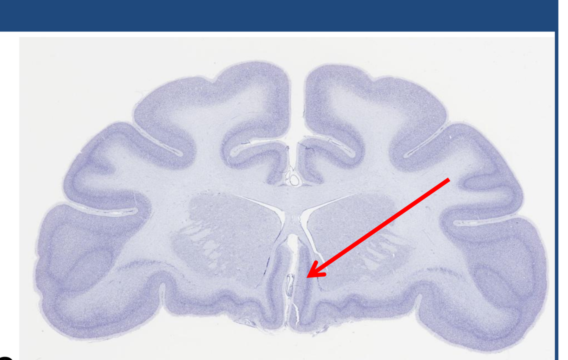
INTRODUCTION

Animal models are crucial for studying human mental health problems, like schizophrenia , addiction, and depression. However, affective disorders are a special challenge when language is not available to measure emotion. One alternative to language is to infer emotional state from autonomic measures, e.g., heart rate, skin conductance and pupil size. For technical reasons, these measures are more difficult to make in the preferred animal model, rhesus monkeys. Methods to manage artifacts that arise from recording autonomic measures are essential for data analysis. The present study is part of a larger project to manage artifacts in electrocardiograms (ECGs) recorded with surface electrodes.

Past experience shows that ECG artifacts in rhesus monkeys are resistant to simple filtering techniques. As the complexity of the signal processing methods expand, developing metrics for the effectiveness of each technique is of paramount importance. This project is to develop such metrics.

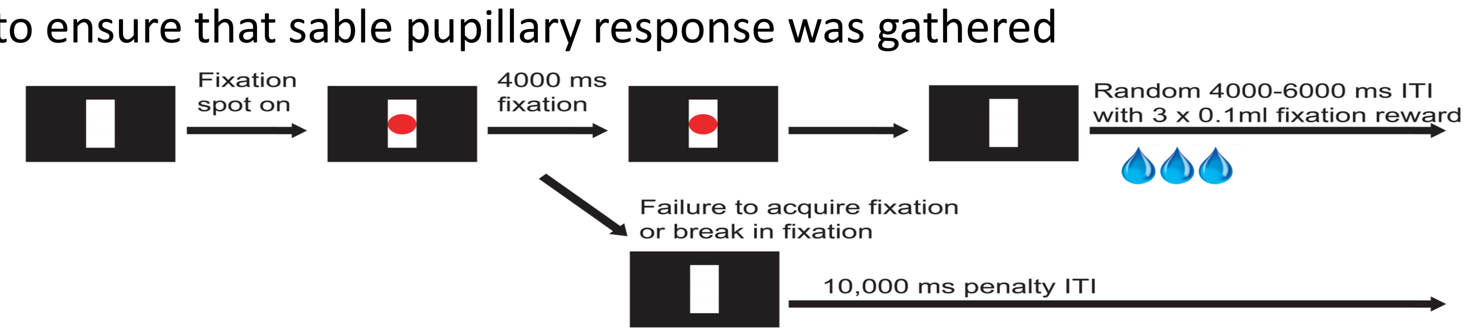
The data used in this project comes from six rhesus monkeys, half with bilateral aspiration lesions of Walker's area 25 of the frontal lobe. The other three served as controls. Walker's area 25 is implicated in the pathophysiology of a number of psychological disorders. Data were collected during a Pavlovian conditioning task, where fluid rewards were delivered either with or without prior warning signals on each trial. Monkeys completed at least 100 trials per day. The relationships among reward, warning signal, and frontal lobe lesions will be assessed with heart rate and other autonomic measurements once the overall project to develop measures is complete.

METHODS

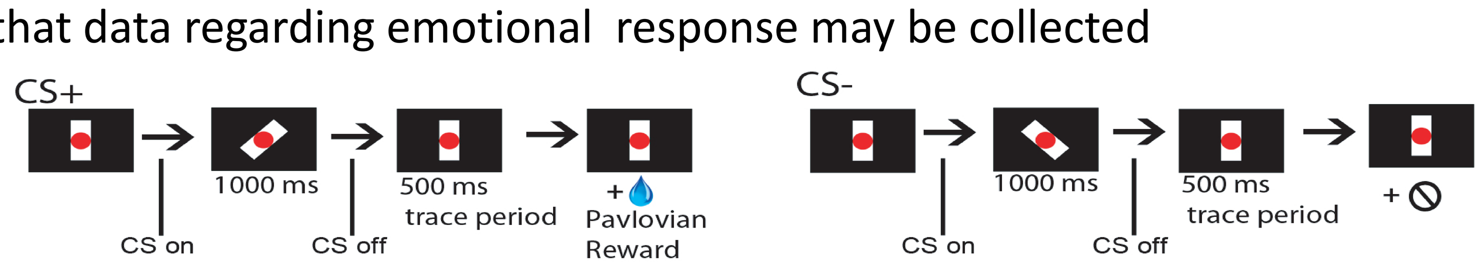


•6 Rhesus Monkeys (*Macaca mulatta*)
-3 with bilateral aspiration lesions of area 25
-3 unoperated controls
•The monkeys were trained in two independent tasks: fixation and Pavlovian
•First monkeys achieved satisfactory criterion in the fixation task then the Pavlovian task was added running independently in conjunction with the fixation task

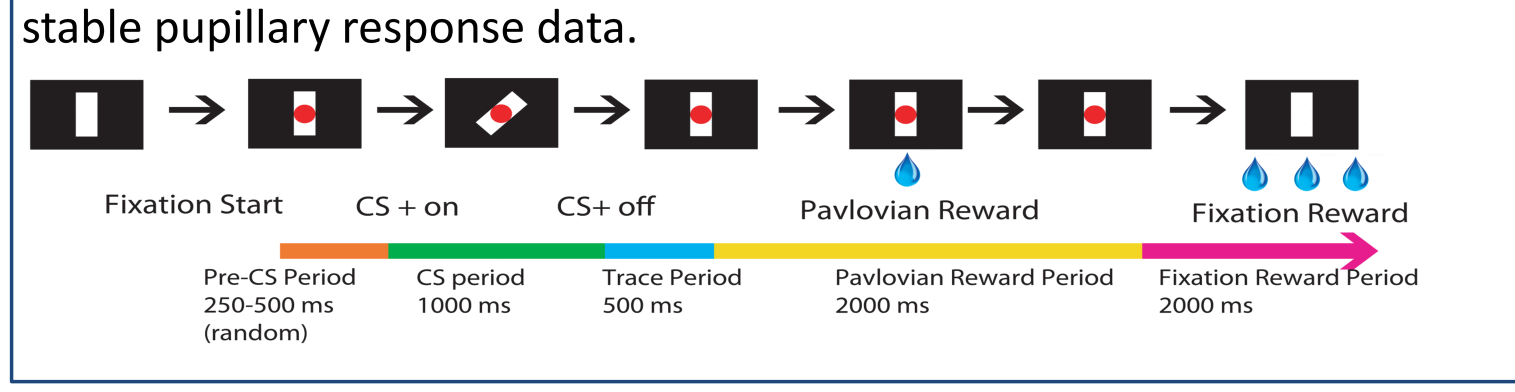
FIXATION: the fixation task was designed to reward the monkey's active gaze to ensure that sable pupillary response was gathered



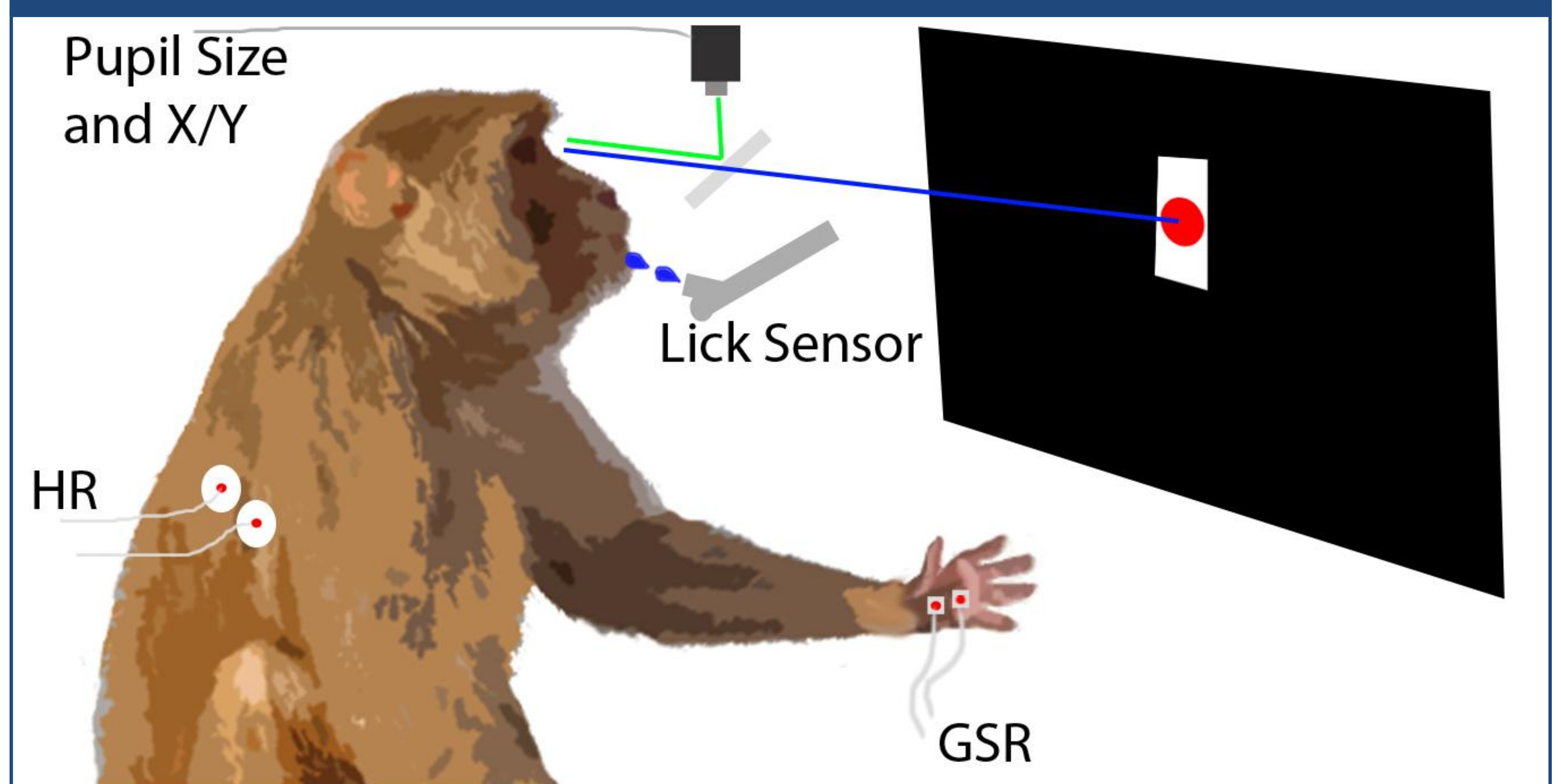
PAVLOVIAN: the Pavlovian task allows the monkey to anticipate a reward so that data regarding emotional response may be collected



When used concurrently together, the two tasks ensure the collection of stable pupillary response data.

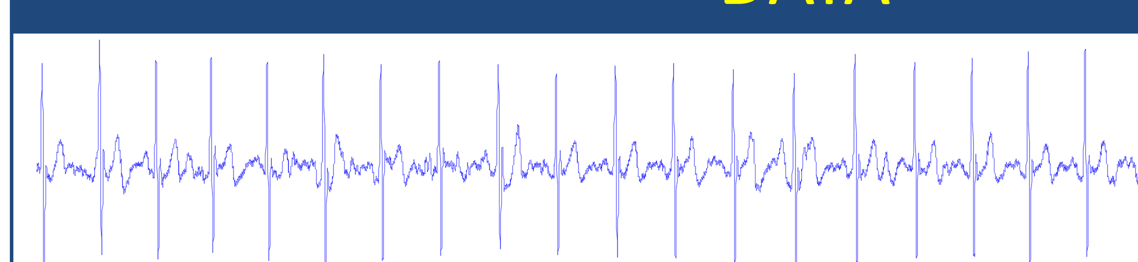


PHYSIOLOGICAL DATA COLLECTION

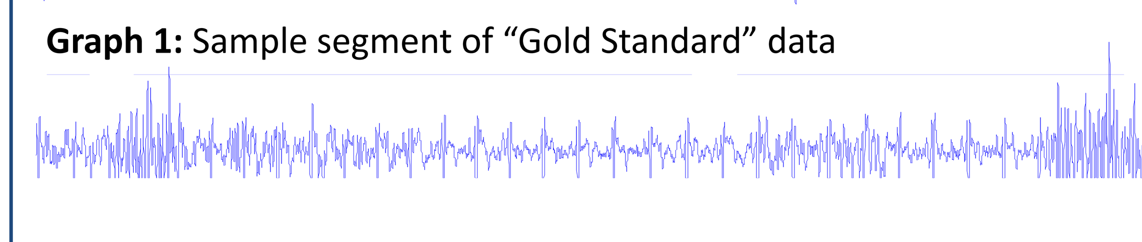


Surface electrodes recorded the electrocardiogram (ECG) for heart rate (HR), and recorded galvanic skin response (GSR). Eye X/Y position and pupil size were recorded with an infrared camera.

DATA



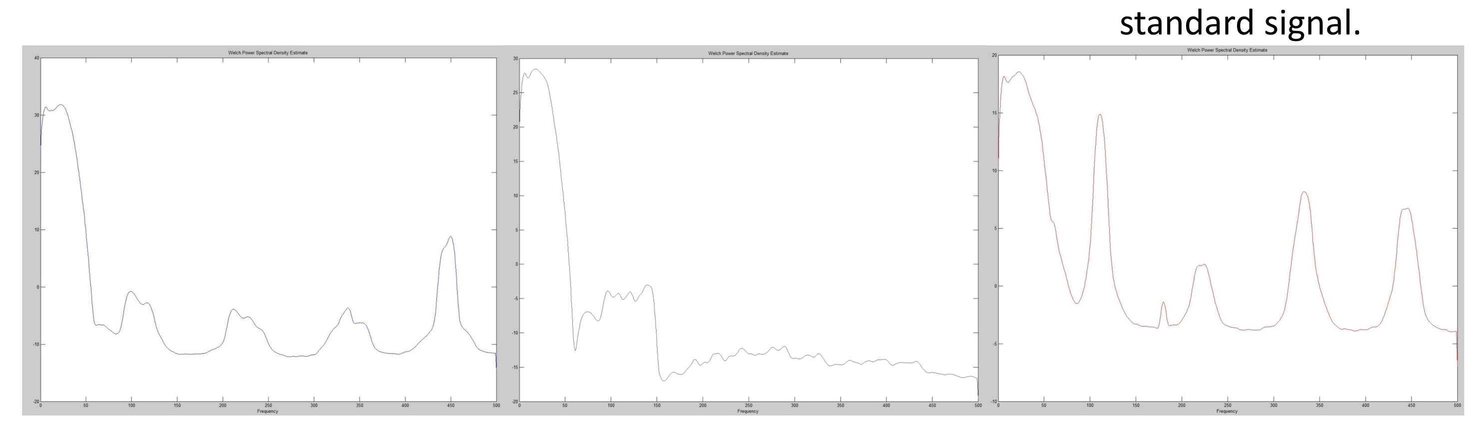
Graph 1: Sample segment of "Gold Standard" data



Graph 2: Sample segment of noisy ECG data

Graph 3: Sample segment of noisy ECG data, R peaks are lost

The ECG data exists in varying degrees of quality because many other electrophysiological signals confound the ECG signal. EMG disturbances are most common and are observed in 2. Poor electrode connections lead to the large impulses in 3. Initial approaches involved using FFT to compare the signals, but the signals all possessed similar spectra. The next attempt involved using the signal distributions. ECG data is compared against a known gold standard signal.

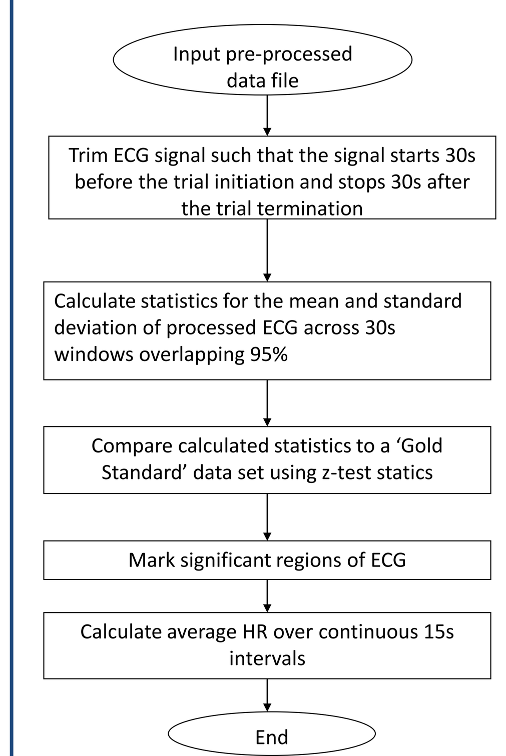


Graph 4 A, B, C: Welch FFT Transforms of the three above signals

CHALLENGES

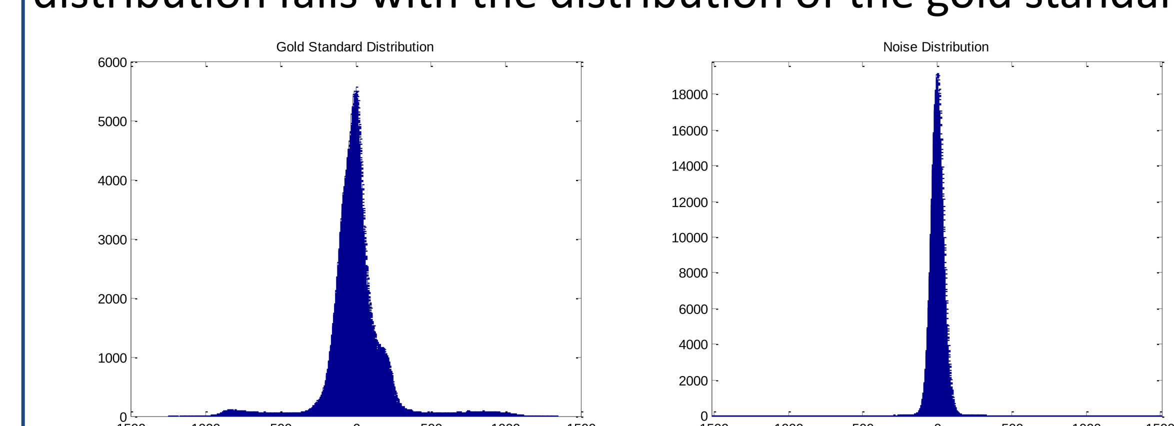
•The body hair of non-human primates (monkeys) provides poor surface contact for electrodes. Ideal recordings are rare, although obtainable **Graph 1**.
•Monkeys can be uncooperative, and will shake or remove electrodes. Shaking can produce major artifacts from changes in electrode-skin impedance. **Graph 2**.
•Electromyographic (EMG) signals are a major contaminate. **Graphs 2, 3.**
•Bandpass filtering resolves some noise issues, but EMG and some shaking artifacts can be very similar to the characteristic "QRS complex" signature of ECG.
•For the same reason, spectral comparisons did not differentiate QRS complexes from the, often larger, artifacts. **Graph 4 A, B, C.**

ALGORITHM



The algorithm first trims extraneous ECG data from the input file. When the test is over, the monkeys can get restless and muddle the ECG signal at the extreme ends of the sample. The z-test statistic can be used because most noise interferences fall within a short time segment when compared to the entire sample. The windowing allows a closer vantage point through which to observe significant aberrations in standard deviation and mean.

•The current algorithm works well when comparing data that contains more ECG signal than noise
•The algorithm fails to detect some noisy signals because the distribution falls with the distribution of the gold standard



Graph 5: Comparison of the gold standard distribution to noise

SUMMARY

RESULTS

Finding other Gold Standard data:
•Out of 527 data files analyzed, only 34 files were identified as differing by less than 10% within 3 standard deviations
•From those 34 files, 13 were visually confirmed to contain no express QRS wave forms

Analyzing single signals:
•In a given signal, specific Pavlovian trials may be discarded because the signal quality over its length grossly misrepresents the true HR
•HRV calculations are needed for lengths of at least 15s
•In a sample of 30 signals, less than 20% of the data contained 15s segments of non-overlapping usable HR calculations

CONCLUSION

The motivation of the work is to study HRV as an indicator of emotional response, but noisy data corrupts the spectra of signals making HRV analysis difficult. The short time lengths involved limit the effectiveness of the FFT in isolating low frequency changes. By cleaning data sets, it is hoped to greatly improve the quality of that analysis. Other non-Pavlovian tasks which are much shorter and of greater variety will also benefit from this area of research. The statistics algorithm is limited in its ability to detect noisy data because it cannot account for data that is more noise than signal; therefore, additional development will need to occur. The next step in the study should concern comparing the spectra of segments of data once the initial analysis with statistics is preformed. This new characteristic will serve to further demonstrate the quality of data segments. Distribution comparisons also seem promising for differentiating between noise and signal data sets.

ACKNOWLEDGEMENTS

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